A FLOATING PROCESS FLOW CONTROL SYSTEM TO HANDLE OPERATION

EVENTS IN A FULL AUTOMATION PLANT

BACKGROUND OF THE INVENTION

(1)   Field of the Invention

The invention relates to a method to control a manufacturing plant, and, more particularly, to an automated manufacturing control system capable of automated handling of operation exceptions.

(2)   Description of the Prior Art

In the field integrated circuit manufacturing, much effort is being expended in the area of automation. In particular, manufacturers are moving toward fully automated fabrication operation or FABs. This movement is occurring due to a desire to reduce labor costs and because of a growing recognition of human limitations encountered in handling ever larger-sized integrated circuit wafers. Referring now to Fig. 1, the architecture 10 of an unmanned FAB is illustrated in a very simplified schematic. The schematic shows a collection of processing equipment EQ1-EQ6 38, 42, 46, 50, 54, and 58. In a wafer FAB, this equipment may

comprise processing tools such as those used to deposit thin films, to perform photolithography, to perform thermal processing, or to implant ionic species as is well known in the art. In the unmanned FAB, production wafers, often collected in batches called lots, move around from equipment location to equipment location by means of an automated transportation system 34. This automated transportation system 34 may comprise fixed material handling conveyances or may comprise smart vehicles or robot devices as are known in the art. Whatever the physical means of movement, the transportation system is controlled by a computer system 26.

A wafer FAB is typically organized around the concepts of work-in progress and dispatching. Integrated circuit manufacturing generally requires many processing steps. Therefore, the total processing cycle time is typically in the range of several weeks. Therefore, at any given time a large quantity of product lots are present in the FAB, and each of these product lots is currently at some step in its overall process flow. The sum total of product lots in the FAB at any given time is called the work-in process or WIP. At any given time, product lots in the total WIP may be moving from WIP storage 30 to a particular process tool EQ1-EQ6, from one tool to another tool, or from a tool to the WIP storage 30.

To run the FAB profitably and to meet customer delivery schedules, it is vital that the manufacturer carefully control the movement of WIP through the process steps and the utilization of the limited processing equipment. The control of WIP movement and equipment utilization is performed by a manufacturing information system (MIS) and dispatch controller 14. In the dispatch process, the controller decides, perhaps under semi-automated control, which product lots from the WIP will be moved into a process tool EQ1-EQ6. The WIP tracking database 22 is used to track the present location of any product lot in the FAB as well as to log the processing history.

Most FABs are capable of producing a variety of integrated circuit devices. Further, different products may require different sequences of process steps or even process steps that are unique to individual products. Therefore, each product or product family will have a unique process flow. These process flows are stored in a main process flow database 18. The MIS/DISPATCH controller 14 accesses the WIP tracking data 22 and the process flow data 18 to determine where a product is in its process flow and where it should go next. In addition to the step sequence, the main process flow database 18 may contain recipe or equipment parameters that are unique for that product

at any given step. This information is passed from the process flow database 18, through the MIS controller 18 and down to the selected process tool EQ1-EQ6 to insure that the product is run with the correct recipe.

The unmanned FAB architecture 10 works well as long as the product lots and the equipment are operating along the strict process flows 18. However, this architecture is not capable of handling operation exceptions while remaining in full-automation mode. Operation exceptions EX1 62, EX2 66, and EX3 70, are unscheduled events that occur during routine operations. Operation exceptions cause the product to deviate from the standard process flows defined in the main process flow database 18. For example, a wafer carrier may reach its cleaning date, or a quality monitoring may reveal a need for an N2 purge operation, or a process tool may reach a maintenance trigger, or a group of monitor lots needs to be created to check equipment performance. Operation exceptions occur very frequently in an operating FAB. However, these events are not governed by the main process flows and are difficult to integrate into the full-automation operation. Therefore, it found that about 50% of the required operator effort in the FAB is expended on servicing these operation exception events. It is therefore desirable to

better integrate operation exception events into the full-automation control architecture.

Several prior art inventions relate to manufacturing control systems. U.S. Patent 5,612,886 to Weng describes a method and a system to perform dynamic dispatching in a semiconductor manufacturing plant. The invention combines the work in progress (WIP) release policy and the dispatching method such that high-priority WIP processing is optimized at the same time throughput is optimized. U.S. Patent 6,546,364 B1 to Smirnov et al describes an adaptive workflow system with a schedule engine and a workflow engine. The workflow engine monitors task execution for deviations of task executions and triggers the schedule engine to build new workflows for as yet uncompleted tasks using a model of the manufacturing environment.

SUMMARY OF THE INVENTION

A principal object of the present invention is to provide an effective and very manufacturable method and apparatus to control an automated manufacturing process.

A further object of the present invention is to provide a control system suitable for an unmanned FAB.

A yet further object of the present invention is to provide a method to handle operation exceptions.

A yet further object of the present invention is to reduce the product cycle time lost while waiting on operator or engineering action due to operation exceptions.

A yet further object of the present invention is to improve equipment efficiency by continuing to process on full-automatic mode during operation exception events.

A yet further object of the present invention is to increase FAB throughput.

A yet further object of the present invention is to save engineering time by reducing the number of possible process flows and conditions that must be maintained in the main process flow database.

In accordance with the objects of this invention, a method to handle operation exceptions in an automated manufacturing

system is achieved. The method comprises providing an automated

manufacturing system comprising a means to track progress of

work in process against standard process flows and a means to

select product lots for processing from the work in process and

to select equipment for processing the product lots based on

next step information from the standard process flows. The

automated manufacturing system is monitored for operation

exception events where the product lots must deviate from the

standard process flows. A floating process flow is selected

corresponding to the operation exception event and the product

lots from a floating process flow database. The floating process

flow is linked to the standard process flow such that the next

step is derived from the floating process flow. Manufacturing is

continued using the floating process flow. The floating process

flow is unlinked from the standard process flow such that the

next step is derived from the standard process flow when the

floating process flow is completed.

Also in accordance with the objects of this invention, an

apparatus to control floating process flows in an automated

manufacturing system is achieved. The apparatus comprises an

operation interface to monitor the automated manufacturing

system for operation exception events where the product lots

must deviate from the standard process flows. A management unit

creates, updates, and deletes floating process flows. A data unit stores the floating process flows. A control unit selects the floating process flows corresponding to the operation exception events.

Also in accordance with the objects of this invention, an apparatus to control an automated manufacturing system is achieved. The apparatus comprises a means to track progress of work in process against standard process flows. A means to select the product lots for processing from the work in process and to select equipment for processing the product lots based on next step information from the standard process flows is included. A means to control floating process flows in an automated manufacturing system is included. The means comprises an operation interface to monitor the automated manufacturing system for operation exception events where the product lots must deviate from the standard process flows. A management unit is used to create, update, and delete floating process flows. A data unit stores the floating process flows. A control unit selects the floating process flows corresponding to the operation exception events.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings forming a material part of this description, there is shown:

Fig. 1 illustrates an architecture of a prior art, automated manufacturing system.

Fig. 2 illustrates a preferred embodiment of the present invention showing a system architecture of an automated manufacturing system capable of handling operation exceptions.

Fig. 3 further illustrates the system architecture of the present invention.

Fig. 4 illustrates a data unit.

Fig. 5 illustrates a context diagram showing the relationship between the main process flow and floating process flows in the present invention.

Fig. 6 illustrates a preferred embodiment of the present invention showing time sequence relationships between various events.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention disclose a method and an apparatus to control a manufacturing plant. In particular, the method and apparatus are directed to handling operation exception events that cause deviation from the standard process flow. The invention allows for full automation operation of the manufacturing process by dynamically connecting the standard process flow to a floating process flow when an operation exception event occurs. It should be clear to those experienced in the art that the present invention can be applied and extended without deviating from the scope of the present invention.

Referring now to Fig. 2, a preferred embodiment of the present invention is illustrated. Several important features of the present invention are shown and discussed below. An apparatus 100 for controlling an automated manufacturing plant is described. As in the prior art case, an MIS/dispatch controller 104 is used to track progress of work in process (WIP) in the WIP tracking database 112 against standard process flows kept in the main process flow database 108. The

MIS/dispatcher 104 selects the product lots for processing from the WIP database 112 and selects equipment for processing the product lots based on next step information from the standard process flow database 108. The MIS/dispatch unit 104 directs the transport control unit 128 to automatically move product in the manufacturing plant as described in the prior art. The equipment is not shown on this schematic for simplification of illustration.

As an important feature of the present invention, a floating process control unit 120 is provided to control floating process flows in the automated manufacturing system. A floating process flow is a standard operation procedure (SOP) that has been constructed to handle a specific operation exception event. For example, a SOP may be generated to handle a type of N_2 purge that occasionally must be performed in connection with a particular process. The floating process flow for this N_2 purge is maintained in a floating process flow database 124 where it can be created, edited, and/or deleted by the engineering staff. Further, the floating process flows in the database 124 can be automatically accessed by the floating process control unit 120 whenever an operation exception event occurs.

As another important feature of the present invention, operation interfaces 116 and 118 monitor the automated manufacturing system 100 for operation exception events where the product lots must deviate from the standard process flows provided by the main process flow database 108. Operation exceptions are preferably registered into the automated manufacturing system in one of two ways. First, an operator graphical interface (GUI) 116 is supplied. Using the operator GUI, a FAB operator can enter an operation exception event by simply clicking with an input device, such as a mouse, or by using a keyboard. Second, the FAB process equipment may be interfaced into the automated control system 100 using, for example, a semiconductor equipment communication standard (SECS) interface. In this way, operation exceptions can be triggered automatically by the process equipment.

In either case, once an operation exception event is logged into the system, the floating process flow control controller 120 automatically selects the correct floating process flow from the database 124. The system then automatically connects the selected floating process flow and the standard process flow for the product lot such that standard process flow effectively branches to the floating process flow beginning at the next process step. Then, the floating process flow is used to direct

the processing of the product lot, step-by-step, until the floating process flow is completed. When the floating process flow has been completed, the chain of control returns to the standard process flow beginning at the processing step where the operation exception occurred. In this way, the present invention handles the operation exception event while maintaining full-automation manufacturing and while substantially limiting operator intervention.

Referring now to Fig. 3, a more detailed architecture for the floating process flow control system 200 is shown. The major process flow data pool 204 contains all the standard product process flows. The operation interface 208 comprises the means for the operator or for the equipment to notify the system 200 of an operation exception event as described above. The floating process flow kernel 212 comprises a management unit 216, a data unit 220, a control unit 224 and a recipe unification unit 228. The management unit 216 allows the process or specification engineer to create, update, and delete floating process flows. The management unit 216 preferably has an isolated user interface accessible to the specification management engineer. The data unit 220 preferably comprises the floating process flow pool 221 and a dynamic data pool 222 as shown in Fig. 4. The floating process flow pool 221 maintains

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the static, standard operating procedures (SOP) for each

floating process corresponding to each type of operation

exception event. The dynamic data pool 222 is used to

temporarily store the connections established between the main

process flows and the floating process flows during exception

event servicing and to temporarily store floating process flows

that are formed at run time by concatenating together smaller,

sub-flows.

Referring again to Fig. 3, the control unit 224 coordinates

the operation of the management unit 216, the data unit 220, and

the recipe unification unit 228. The control unit 224 preferably

acts like a neural system. The recipe unification unit 228 is

used to unify floating process flows that have the same process

capacity. Operation exception events can occur at many steps in

the main product flows. Therefore, handling all the possible

types of exceptions at all the possible entry points in the main

flows can create a large number of floating process flows. To

reduce the proliferation of floating process flows, it is

preferred that the floating process flows be stored in the

smallest, most common units or sub-flows. When an exception

occurs, the recipe unification unit 228 then builds the floating

process flow that will be used to process the exception by

selecting and tying together the sub-flows. The recipe

unification unit 328 selects sub-flows having the same process

capacity to create an optimal floating process flow for the

particular operation exception event in its context. As

described above, the kernel 212 is connected to the

transportation system 232 and to the dispatch system 236. The

transportation system controls movement of the product lots from

equipment-to-equipment, equipment-to-WIP storage, and WIP

storage-to-equipment. The dispatch system 236 helps to optimize

equipment utilization and process cycle time. Each product lot

may have several equipment candidates for the next process step.

The dispatch system 236 chooses the optimal tool.

Referring now to Fig. 5, a context diagram 300 is shown to

further illustrate the concepts of the present invention. For an

integrated circuit manufacturing plant, the product lots start

in a start bank 304. When a product lot moves out of the start

bank 304, it moves into the first step 316 in its process flow.

The standard process flow for a product is illustrated by steps

1, 2, 3, ...n-1, and n as shown. After processing in step 1 316,

the product moves to step 2 320, then to step 3 324, then

continues until moving to step n-1 328 and finally to step n

332. After step n 332 is completed, the product lot moves into

the end bank 308 which may be the end of all FAB processing or

may be a holding area, such as prior to an upper metalization,

for WIP awaiting final configuration.

As the product lot moves along the main process flow,

operation exception events may occur. In this example, a first

operation exception, an N_2 purge 336, occurs as the product is

moved into the first step 316. In the present invention, the

indication of a needed N_2 purge may be made by an operator mouse

click at the operator GUI described above. In response to the

exception, the control system of the present invention

automatically accesses the floating process flow data pool 312.

Note that the data pool 312 may contain several flows 336 and

340 that correspond to an N_2 purge. However, the system selects

the N_2 purge floating flow 336 that corresponds to the equipment

and/or product combination where the exception occurs. The

control system makes the proper connection between the selected

floating flow 336 and the main flow such that the next step for

move in of the product lot becomes the first step in the N_2 purge

flow 336. Next, the N_2 purge flow is automatically run using the

automated operation of the equipment and transportation system.

When the N_2 purge flow 336 is completed, then the next step is

set for the step where the exception occurred which is, in this

case, the first step 316 in the main flow.

Another exception occurs at the move in to the third step 324. Again, an N_2 purge flow 336 is required. At the move-in to the n-1 step 328, another N_2 purge exception is required. In this case, however, the N_2 purge fits a different floating flow 340 from the data pool 312. At the move-in to the n step 332, a monitor lot exception is encountered. The monitor lot preparation floating flow 344 is selected and automatically performed by the system. Other exception events illustrated include carrier replacement 352, product rework 348, and carrier cleaning 356.

Referring now to Fig. 6, a time sequence table 400 is illustrated to show how the system performs in a typical exception event. In the example, in step 1, the specification management engineer inputs a floating process flow into the floating process flow data pool using the management unit. The floating process flow is unified by the recipe unification unit. In step 2, the operation interface receives an external trigger and passes the notification to the control unit. The trigger may come from the operator or from the equipment. In step 3, the control unit extracts a proper floating process flow from the data unit and then connects this floating process flow to the standard process flow. In step 4, the control unit commands the transportation unit to move the lot to the process tool as

specified by the first step in the floating process flow. In step 5, the lot processing proceeds along the floating process flow under the control of the automated dispatching system and the transportation system in full automation mode. Finally, in step 6, after completing the floating process flow, the lot is moved back to the standard process flow and the connection between the standard and floating flows is destroyed.

In yet another preferred embodiment of the present invention, the system may modify the floating process flow or sub-flow in response to an operation exception event to embed specific information into the recipe. Some recipe information can be included in the floating process flow data. For example, the process flow may specify a particular recipe name or identifier to be used in the tool during processing. Further, the recipe identifier may have an embedded token to specify product information, lot information, or equipment information. Alternatively, a recipe parameter may be included in the floating process flow information and this parameter may specify product information, lot information, or equipment information. An example of this token information is shown in Table 1 below where the product identifier is "TM1234A567", the reticle group is "1234120A", the available chambers are "1,2,3", the non-available chambers are "4", and the @ENERGY IS "042".

Number	Embedded Token	Description	Example
1	{P6}	First 6 chars of product ID	ABC{p6}DEF→ABC**TM1234**DEF
2	{P7}	First 7 chars of product ID	ABC{p7}DEF→ABC**TM1234A**DEF
3	{RG}	Reticle group	ABC{RG}DEF→ABC**1234120A**DEF
4	{C}	All available chambers	ABC{C}DEF→ABC**123**DEF
5	{Cddd}	Specific available chambers	ABC{C24}DEF→ABC**2**DEF
6	{C(d1,d2)}	Chose **one** available group of specific chambers	ABC{C(12,3)}DEF→ABC**12**DEF
7	{C[d1,d2]}	Chose **all** of available group of specific chambers	ABC{C(12,3)}DEF→ABC**123**DEF
8	{@PARAM}	Replace tag by external parameter	ABC{@ENERGY}DEF→ABC**042**DEF

TABLE 1. A set of embedded tokens.

The advantages of the present invention may now be summarized. An effective and very manufacturable method and an apparatus to control an automated manufacturing process are achieved. A control system suitable for an unmanned FAB is provided. A method to handle operation exceptions is provided. The product cycle time lost while waiting on operator or engineering action due to operation exceptions is reduced. The equipment efficiency is improved by continuing to process on

full-automatic mode during operation exception events. The FAB

throughput is increased. Engineering time is saved by reducing

the number of possible process flows and conditions that must be

maintained in the main process flow database.

As shown in the preferred embodiments, the novel method and

apparatus of the present invention provides an effective and

manufacturable alternative to the prior art.

While the invention has been particularly shown and

described with reference to the preferred embodiments thereof,

it will be understood by those skilled in the art that various

changes in form and details may be made without departing from

the spirit and scope of the invention.

What is claimed is: